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# Equations for calculating ideal body weight in patients on mechanical ventilation in adult intensive care units in Latin America: exploratory review

*Ecuaciones para calcular el peso ideal en pacientes con ventilación mecánica en unidades de cuidado intensivo adulto en Latinoamérica: revisión exploratoria*

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## What do we know about this problem?

- Ideal weight calculation requires accurate height measurement, a procedure which is not standardized in many intensive care units.
- In intensive care, the reference equation used to calculate the ideal weight is the one proposed by the Acute Respiratory Distress Syndrome Network (ARDSnet) guideline which was designed on the basis of anthropometric measurements of the United States population.

## How does this study contribute?

- It highlights the importance of standardizing and/or creating a protocol for measuring height in critically ill patients.
- It creates interest regarding the need to design predictive equations for calculating ideal weight based on anthropometric variables for the Latin American population.

## How to cite this article

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## Abstract

### Introduction

Ideal body weight calculation is used in critical medicine for drug dosing and setting ventilation parameters. However, the suggested and used equations were designed on the basis of anthropometric variables that do not represent the Latin American population.

### Objective

To map and present the current evidence on the equations used to calculate ideal weight in patients on mechanical ventilation in intensive care units in Latin America.

### Material and Methods

Exploratory review using the Joanna Briggs Institute method conceived by Arskey / O'Malley. A search was performed in the BVS, LILLACS, REDALYC, Ovid, Google Scholar and Scielo databases using keywords and MeSH terms in Spanish, English, and Portuguese, with no time limitation. The results are presented in descriptive tables.

### Results

Overall, 1126 studies were identified and 1120 were excluded; 6 studies were reviewed and 3 additional studies were identified through a manual search. The studies were published in Chile, Brazil, Mexico, Ecuador, and Peru. In 89%, the ARDS Network equation was used to calculate tidal volume. Acute respiratory distress syndrome was the most reported pathology (33%).

### Conclusions

Adult intensive care units in Latin America use the equation suggested by the ARDS Network, which was designed in a population with different anthropometric characteristics.

### Keywords

Respiration, artificial; critical care; tidal volume; body height; ideal body weight.

## Resumen

### Introducción

El cálculo del peso ideal se utiliza en medicina crítica para dosificación de medicaciones y programación de parámetros ventilatorios; sin embargo, las ecuaciones sugeridas y usadas fueron diseñadas con variables antropométricas que no representan la población latinoamericana.

### Objetivo

Mapear y presentar la evidencia actual de las ecuaciones utilizadas para calcular el peso ideal en pacientes con ventilación mecánica en unidades de cuidado intensivo de Latinoamérica.

### Material y métodos

Revisión exploratoria con el método del Instituto Joanna Briggs concebido por Arskey y O'Malley. Se realizó una búsqueda en las bases de datos BVS, LILACS, Redalyc, Ovid, Google Scholar y SciELO con el uso de palabras clave y términos MeSH en idiomas español, inglés y portugués, sin límites de tiempo. Los resultados se presentan de forma descriptiva.

### Resultados

Se identificaron 1.126 estudios, se excluyeron 1.120, se revisaron seis y se encontraron tres adicionales mediante búsqueda manual. Los estudios fueron publicados en Chile, Brasil, México, Ecuador y Perú. En el 89 % se usó la ecuación del ARDS Network para calcular volumen corriente. El síndrome de dificultad respiratoria aguda fue la patología más informada (33 %).

### Conclusiones

En las unidades de cuidado intensivo adulto de Latinoamérica se usa la ecuación sugerida por el ARDS Network diseñada en población con características antropométricas diferentes.

### Palabras claves

Respiración artificial; cuidados críticos; volumen de ventilación pulmonar; estatura; peso corporal ideal.

## INTRODUCTION

Ideal body weight (IBW) is similar to healthy body weight and is associated with good health condition. It is determined using equations that include anthropometric variables such as height, weight, sex and/or one or several body segments like the arm or leg; these predictive equations are used routinely by healthcare professionals (1).

Sometimes, body weight measurements - specifically in intensive care units - cannot always be made directly due to the lack of appropriate tools and the patient's condition and, therefore, subjective estimates influence the result. In such cases, equations that can be used to calculate ideal weight are needed (2). However, most equations have been designed using anthropometric variables that are not

representative of the whole population spectrum, and their use overestimates ideal weight, with repercussions in critically ill patients (3).

IBW calculation is widely used in critical medicine for drug dosing, ventilator settings, glomerular filtration rate adjustments, and nutritional assessment (4). However, the equations suggested and used for the calculation originated in the United States and do not consider the very different anthropometric characteristics (weight/height) of the Latin American population.

In particular in adult intensive care units (ICUs), height measurement to estimate ideal weight is very important when it comes to determining tidal volume in patients on mechanical ventilation in order to obtain an objective, effective and preventive determination of lung

ventilation and avoid and/or reduce events or complications related to inadequate tidal volume settings (5).

The Acute Respiratory Distress Syndrome Network (ARDS Network) guidelines suggest that low tidal volumes should be used in patients with acute lung injury and acute respiratory distress syndrome. Moreover, they propose an equation to calculate ideal body weight based on body height measurements. This equation, created on the basis of anthropometric measurements in the United States population, is still the gold standard for ideal weight calculation in the ICU (6).

The consequences of inadequate ideal weight estimation in critically ill patients include ventilation-related complications, considering that over or underestimations of this variable result in wrong tidal volume calculations for ventilator settings. This can

result in lung trauma, such as volutrauma, barotrauma, atelectrauma, inflammatory cascade activation, longer mechanical ventilation, and increased ICU length of stay (7).

Because body height can be influenced by environmental factors, equations for estimating ideal weight that include this anthropometric variable must be designed and validated in accordance with the characteristics of the target population. Notwithstanding, there are no known studies that have designed and proposed other equations to calculate body height in the Latin American population (8). This exploratory review maps the evidence related to the equations used to calculate ideal weight in patients on mechanical ventilation in adult ICUs in Latin America.

## METHODS

This review followed the guidelines contained in the checklist for the presentation of exploratory reviews of the PRISMA-ScR declaration and was based on the Joanna Briggs Institute (JBI) method initially developed by Arksey and O'Malley (9), which was based, in turn, on the methodological guidance set forth by Peters et al. (10) that suggests: formulation of the research question, identification of relevant studies, study selection, data extraction, summary and reports of the results, and conclusions.

## Research question

The following PICO question was built to guide the exploratory review: Which are the equations used to calculate ideal weight in patients on mechanical ventilation in intensive care units in Latin America? The question was designed on the basis of population, intervention, comparison and results: P (Population): Adult patients on invasive mechanical ventilation. I (Intervention): Reference equations for ideal weight calculation. C (Comparison):

Not relevant. O (Outcomes): Ideal weight calculation (Figure 1). Comparison/control was not taken into consideration as it was not considered relevant during the development of the research given that there was no control group for outcome comparisons.

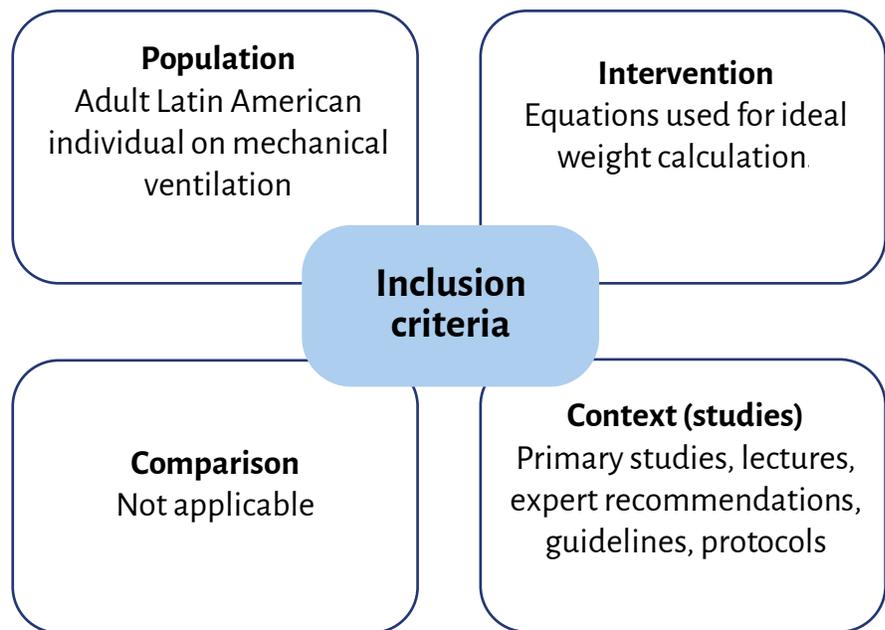
## Selection of studies

Selected studies had to meet the following inclusion criteria: 1) Primary scientific studies, reviews, expert recommendations,

lectures, guidelines or protocols published in Spanish, English and Portuguese. 2) Potentially relevant studies that answered the research question, whether published or not. 3) Studies carried out in adult Latin American population.

Studies that met the following criteria were excluded: 1) Studies that did not provide sufficient information about the equation used for calculating ideal weight. 2) Studies in which ideal weight was calculated but was used for calculations other than ventilation parameters

**FIGURE 1.** Inclusion criteria used on the basis of population, intervention and context.



**SOURCE:** Authors, from González-Seguel, et al. (11)

## Types of participants

Selected studies described, in the methodology, the use of equations for estimating ideal weight in adult patients on mechanical ventilation in different intensive care units in Latin America.

## Concepts

The relevant concepts for this review included the following:

- **Intensive care units (ICUs).** Intensive care consists of providing automated monitoring of multiple parameters for the management of patients with multi-organ decline, supplementary testing, basic and advanced bedside support devices and a multidisciplinary clinical team (12). This services provides care to critically ill patients with any type of disease condition (multiple trauma, surgery, respiratory disease, coronary heart disease, among others), in close collaboration with all other hospital services, in particular the emergency service (13).

In Latin America, the first intensive care units were established in the late 1960s and early 1970s. It can be safely stated that intensive care units can be found in all Latin American countries, managed by intensive care physicians and equipped with sufficient technology to provide adequate management as needed (14).

• **Ideal weight.** It refers to a similarity with the body weight associated with good health condition. For decades, multiple equations have been used to calculate ideal weight, taking into account different body measurements such as height, body weight, ulnar length and even body mass index (15).

Ideal weight is very useful in intensive care units and, specifically, in the area of mechanical ventilation, as an essential tool for calculating tidal volume settings for objective and effective ventilation as well as for preventing ventilation-related events such as volutrauma, barotrauma, atelectrauma, inflammatory cascade activation, length of mechanical ventilation, need for re-intubation and length of ICU stay (7).

• **Body height.** More sensitive than weight, this parameter is used to determine growth in length; it is critical for anthropometric assessment and essential for creating indicators involved in nutritional diagnosis, and dietary and pharmacological prescriptions (16).

• **Mathematical equation.** From the Latin word *aequatio*, it constitutes an equality in which there is at least one unknown quantity that needs to be revealed by the person solving the question. Each of the algebraic expressions that allow to discover linked data and unknown quantities through various mathematical operations are known as members.

• **Mechanical ventilation (MV).** Therapeutic option which, based on the understanding of the pathophysiological mechanisms of respiratory function and with the help of technological advances, offers the

opportunity to provide efficient life support to critically ill patients in respiratory failure (17).

• **Tidal volume (TV).** Gas volume that circulates between normal inspiration and expiration. In mechanical ventilation, a volume between 6 and 8 mL per kilogram of ideal body weight may be programmed in patients without lung compromise (18).

• **Protective ventilation.** It is defined as a mechanical ventilation strategy in which low tidal volume and minimum airway pressure are used in order to prevent associated complications (17). Meta-analysis reports and randomized studies have shown that protective mechanical ventilation reduces short-term mortality (19).

### Identification of relevant studies

The literature search was conducted by two physical therapists with more than 4 years of intensive care experience, advised by a biomedical librarian. The process of study identification, review, eligibility and inclusion was carried out by consensus between the researchers. Studies conducted in any Latin American country in the context of adult ICUs were selected.

### Search strategy

This review used primary sources in the form original published research articles, and secondary sources in the form of existing reviews on the topic described but which included studies carried out in the Latin American population. Unpublished evidence was also included, such as results of research that met the predefined selection criteria, conducted by specialization, master's and PhD programs.

A complete search was carried out in three phases to identify published and unpublished literature on the core theme of this review: a preliminary search in the BVS, LILACS, Ovid, and SciELO databases using the keywords artificial respiration,

pulmonary ventilation volume, algorithms, body size, mathematical concepts, reference values, body weight, ideal body weight in Spanish, English and Portuguese without time or language restriction. Additional keywords most frequently used in the relevant studies that met the inclusion criteria for this review were identified from the analysis of the results of the preliminary search.

A second search was conducted using all the keywords derived from the previous phase, but this time expanded to other databases (Redalyc and Google Scholar). In the final phase, the references listed in the articles and reviews previously selected were reviewed in depth to identify other studies and key authors to contact in order to identify primary studies or reviews not yet published or in process of publication. Time limits were not taken into account for the search and articles published in Spanish, English and Portuguese were included.

Key words sorted according to the PIO question were defined, allowing to develop a search equation with the main structured descriptors and qualifiers, and leading also to a higher degree of accuracy to localize linked terms in the articles included in the literature database of interest for the review. The general search was as follows: P—Respiration, Artificial OR Tidal Volume—, I—Algorithms OR Size OR mathematical concepts OR Reference values—, O—Body Weight OR Ideal Body Weight—.

A search restriction was established as a specificity strategy with the aim of eliminating noise or the number of irrelevant studies, achieving thoroughness, and arriving at the maximum possible number of studies that contained the information relating to the research question.

To initiate the search, the concepts in the BVS and PubMed portal databases were normalized. An advanced literature search was then conducted in the databases listed in Table 1, using DeCS/MeSH terms in English, Spanish and Portuguese, and a specific search equation for each.

The database search was completed manually with the review of the bibliographic references of the articles retrieved, in order to ensure a thorough search. This process was repeated several times in order to make sure no useful studies were overlooked.

A search of the grey literature was also conducted through the Opengrey.eu site, with no results.

## Data extraction

Having completed the identification and selection phase, the researchers read the articles and prepared a descriptive table with the most relevant data. One team member removed duplicate articles and screened the remaining studies based on the information extracted from the title, the abstract and the full text, classifying it as relevant and not relevant in accordance with the pre-determined inclusion criteria. Quality control of the selection process was performed by the second researcher who assessed the excluded articles in order to ensure that no relevant information was lost. No discrepancies between researchers occurred. [Table 2](#) describes the characteristics of the articles: author, year of publication, country of origin and context of the study, objectives, study population, sample size, methodology, variables, intervention description, and results.

## Presentation of the results

The results of the review are presented in descriptive tables that show relevant aspects pertaining to the studies, including study type, type of population, sample size, country of origin of the study, equation used. Moreover, a flow diagram describing the search process and the final number of studies included is presented.

## RESULTS

Overall, 1,126 studies were identified using the search equations. Following the initial selection, relevance in relation

to the inclusion and exclusion criteria was assessed, resulting in 1,120 studies discarded, and 6 retained; 3 additional studies were identified through the manual search from the list of references that met the inclusion criteria. Ultimately, this review included a total number of 9 studies ([Figure 2](#)).

Of the selected studies, 56% were review articles, 22% were prospective cohort studies, 11% were clinical practice guidelines and 11% were retrospective observational studies.

The studies found were published over a 13-year period, between 2004 and 2017. In 100% of the studies, it was found that the ideal weight calculation was used for calculating tidal volume. Studies were carried out in Chile, Brazil, Mexico, Ecuador and Peru.

Various disease conditions were identified in the articles, the highest in percentage terms being acute respiratory distress syndrome (ARDS) (33.3%), followed by acute respiratory failure syndrome (ARFS) (22.2%), acute lung injury (11.1%), and influenza A H1N1 (11.1%). Of the included studies, 89% used the ARDSnet equation for ideal weight calculation. Only one study, carried out in Mexico, used the 50th percentile equation of the Hispanic Health and Nutrition Examinations Survey ([Table 3](#)).

## DISCUSSION

This review explored the evidence related to the use of equations for estimating ideal weight in adult patients on mechanical ventilation in Latin American ICUs.

This evidence review found that in countries like Mexico, Ecuador, Chile, Peru and Brazil the ARDSnet equation is used for calculating ideal weight in critically ill patients. This equation, created in 2000 from the ARMA study ([6](#)) was the most widely reported despite the fact that it was created on the basis of anthropometric measurements and estimations in people with very different biotypes, ethnicity and race when compared to the Latin American

population, potentially giving rise to over or underestimations, thus affecting their specific use.

In terms of the design and methodology of the 9 studies included in the review, 56% were reviews, 22% prospective cohort studies, and none of them described in the methodology the height measurement protocol used for calculating ideal weight with the ARDSnet.

Research studies and clinical practice guidelines indicate ideal weight calculation in patients on mechanical ventilation using the ARDSnet calculation, which includes body height and gender as variables: males:  $50+0.91 \times (\text{height in cm}-152.4)$  and females:  $45.5+0.91 \times (\text{height in cm}-152.4)$ . However, no standardized methods are described for accurate and reliable measurement of body height in critically ill patients. Similar to the results found in a survey conducted by García-Martínez et al. ([28](#)), it is the opinion of the authors of this review that units where no weighing tools are available (hanging scales or bed scales), continue to use visual and subjective estimates.

The studies in this review found that, in Latin America, the clinical conditions in which the ARDSnet equation was used for calculating ideal weight were ARDS (33%), acute respiratory failure (22%) and A H1N1 pneumonia (11%), perhaps due to the fact that the ARMA study, from which the equation was derived, proposed low-volume lung ventilation (6 mL/kg/ideal weight) as a strategy, showing that mortality was lower and there were fewer ventilation-related complications ([6](#)). However, although the equation requires measuring body height, none of the studies describe the technique or the standardization of the measurement protocol.

In the absence of predictive equations for calculating ideal weight in critically ill patients designed for the Latin American population, the ARDSnet equation continues to be the best option, which implies the need for accurate height measurement.

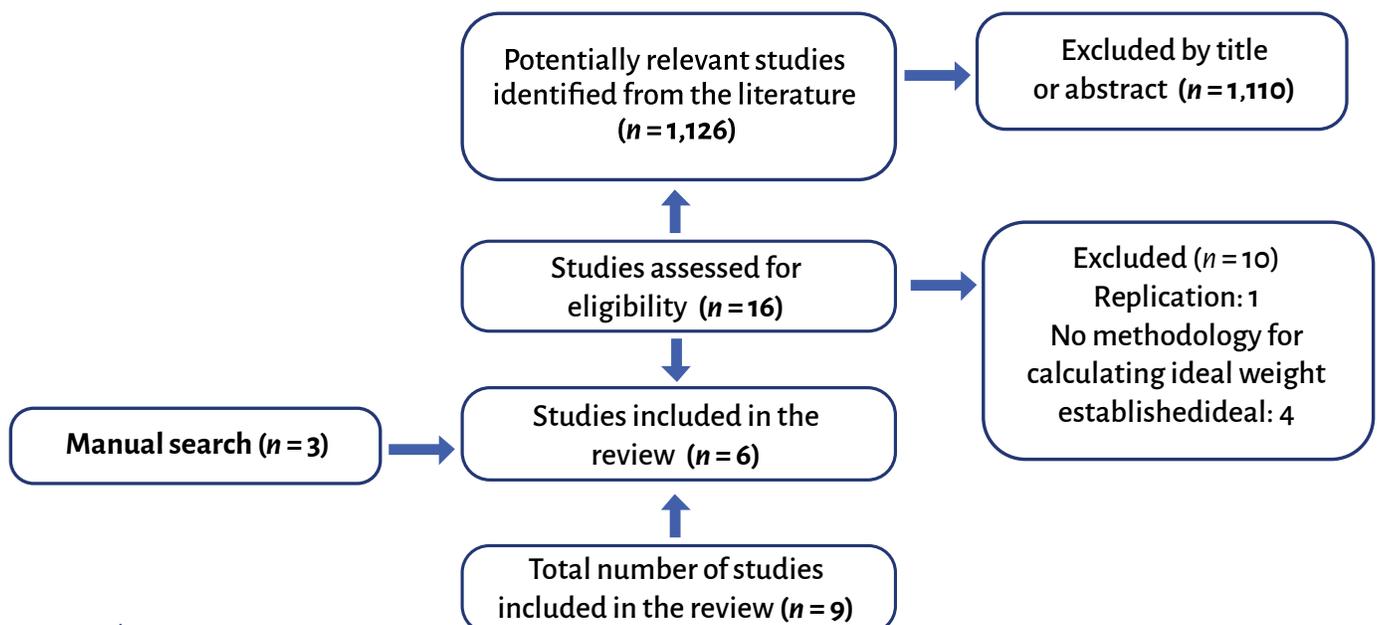
With this review, the authors highlight the importance of standardizing and/or formalizing height measurements in critically ill patients, and the influence of the

**TABLE 1.** Database-specific search strategy.

Database	Search equation	Results	Number of studies that met the inclusion criteria
Regional BVS portal (MEDLINE-LILACS-IBECS)	* (tw:(Respiration, Artificial)) OR (tw:(Tidal Volume)) AND (tw:(Algorithms)) OR (tw:(Reference values)) OR (tw:(mathematical concepts)) OR (tw:(Body Size)) AND (tw:(Body Weight)) OR (tw:(Ideal Body Weight))	English: 245 Spanish: 51 Portuguese: 62	0
SciELO	(respiración artificial) OR (peso ideal) OR (volumen de ventilación pulmonar) AND subject_area:("Health Sciences") AND wok_subject_categories:("medicine, general & internal" OR "anesthesiology" OR "nutrition & dietetics" OR "nursing" OR "medicine, research & experimental")	177	4
OVID (MEDLINE, ACP Journal Club, Cochrane, Database of Abstracts of Review of Effects, Health Technology Assessment, NHS Economic Evaluation Database).	Respiration, Artificial OR Tidal Volume AND Algorithms OR Body Size OR Mathematical Concepts OR Reference Values AND Body Weight OR Ideal Body Weight	68	0
Google Scholar	<b>EQUATION #1:</b> care OR intensive "IBW" With all words: IBW With at least one word: Intensive Care <b>EQUATION #2:</b> mechanical ventilation, height,"ideal body weight"	#1: 344 #2: 162	#1: 3 #2: 6
Redalyc	"Tidal volume" + "Ideal body weight"	20	3

\*A search was conducted with this equation in English, Spanish and Portuguese.

**SOURCE:** Authors.

**FIGURE 2.** Study selection in databases.

**SOURCE:** Authors.

**TABLE 2.** Summary of study findings.

Author, year/ country	Diagnosis	Study design	Sample size	Ideal weight equation	Purpose of obtaining ideal weight	Results
Olvera Guzmán et al., 2004 (20)/ México	Group A: ARFS and Group B: no ARFS connected to MV	Prospective cohort study	203 patients	50th percentile of the Hispanic Health and Nutrition Examinations Survey	TV setting	Adequate adherence to international recommendations regarding the use of MV in patients with ARFS
Domínguez Cherit et al., 2009 (21)/ México	Influenza A H1N1 connected to MV	Clinical practice guideline	N/A	M: $50+2.3$ [Height (inches)-60] F: $45.5+2.3$ [Height (inches)-60]	TV settings	MV strategies defined in critically ill patients with Influenza A H1N1 and respiratory failure
Tominic et al., 2010 (22)/ Chile	ARDS connected to MV	Review article	N/A	M: $50+0.91 \times (\text{height in cm}-152.4)$ F: $45.5+0.91 \times (\text{height in cm}-152.4)$	Tidal volume settings in patients with ARDS	Mechanical ventilation settings in patients with ARDS is still controversial
Paredes et al., 2010 (23)/ Ecuador	ARDS connected to MV	Prospective cohort studies	24 patients	H: $50+0.91 \times (\text{altura In cm}-152.4)$ M: $45.5+0.91 \times (\text{altura en cm}-152.4)$	TV settings	Over a 2-month period, 24 patients were admitted to the ICU with suspected influenza A H1N1. All of the patients presented with severe hypoxemia on admission; 100% required MV; mortality in this group of patients with invasive and non-invasive ventilation was 16.6%
Seiberlich et al., 2011 (24)/ Brasil	ALI and ARDS connected to MV	Review article	N/A	M: $50+0.91 \times (\text{height in cm}-152.4)$ F: $45.5+0.91 \times (\text{height in cm}-152.4)$	TV settings	Protective ventilation could minimize end-expiratory stretching and potential inflation/alveolar collapse
Gutiérrez Muñoz, 2011 (18)/Perú	ARFS connected to MV	Review article	N/A	M: $50+0.91 \times (\text{height in cm}-152.4)$ F: $45.5+0.91 \times (\text{height in cm}-152.4)$	Initial settings/TV change	Detailed description of the mechanical ventilator, use mode, ventilation parameters, indications and physiological effects
Bugedo et al., 2014 (25)/ Chile	Brain death connected to MV	Review article	N/A	M: $50+0.91 \times (\text{height in cm}-152.4)$ F: $45.5+0.91 \times (\text{height in cm}-152.4)$	TV settings in the potential cadaver donor	It is essential to maintain adequate perfusion, protective ventilation strategy and metabolic/hormonal support of the potential cadaver donor
Rocha Rossi et al., 2014 (26)/Brasil	Obesity connected to MV	Review article	N/A	M: $50+0.91 \times (\text{height in cm}-152.4)$ F: $45.5+0.91 \times (\text{height in cm}-152.4)$	TV settings	Existing data suggest protective ventilation strategy with low TV, recruitment maneuvers and higher PEEP in obese patients during surgery.
Gálvez Blanco et al., 2017 (27)/México	Patients subjected to NIMV	Retrospective observational study	40 patients	H: $(\text{Height in cm}-152.4) \times 0.91+50$ M: $(\text{Height in cm}-152.4) \times 0.91+45.5$	TV monitoring as predictor of NIMV failure	Initial TV and after 6 hours of NIMV is not a predictor of failure of this therapy

ALI: acute pulmonary injury; ARDS: acute respiratory distress syndrome; ARFS: acute respiratory failure syndrome; MV: mechanical ventilation; NIMV: non-invasive mechanical ventilation; N/A: not applicable; PEEP: positive end-expiratory pressure; TV: tidal volumen.

**SOURCE:** Authors.

**TABLE 3.** Summary and characterization of the studies.

Author	Sample	Diagnosis	Year	Equation	Country
Olvera Guzmán et al. (20)	N/A	Group A: Patients with ARFS and Group B: patients without ARFS	2004	50th percentile of the Hispanic Health and Nutrition Examinations Survey	México
Domínguez et al. (21)	N/A	Influenza A H1N1	2009	ARDSnet	México
Tominic et al. (22)	N/A	ARDS	2010	ARDSnet	Chile
Paredes et al. (23)		24 patients/ARDS	2010	ARDSnet	Ecuador
Seiberlich et al. (24)	N/A	Patients without pulmonary injury, patients with ALI and ARDS	2011	ARDSnet	Brasil
Gutiérrez (18)	N/A	Patients with ARFS	2011	ARDSnet	Perú
Bugedo et al. (25)	N/A	Patients with brain death	2014	ARDSnet	Chile
Rocha et al. (26)	N/A	Obese patients	2014	ARDSnet	Brasil
Gálvez et al. (27)		40 patients/Patients with hypoxic ARFS	2017	ARDSnet	México

ALI: acute lung injury; ARDS: acute respiratory distress syndrome; ARFS: acute respiratory failure syndrome; N/A: not applicable.

**SOURCE:** Autores.

method utilized on the interpretation of the clinical outcomes; and, moreover, of creating interest regarding the design of predictive equations for the calculation of ideal weight based on anthropometric variables in the Latin American population. Future research should focus on the design and validation of equations in our population.

The strength of this review lies in the selection process guided by the Joanna Briggs Institute (JBI) tool. Difficulty searching the grey literature in an attempt at identifying relevant unpublished material was found to be a limitation.

In conclusion the equation proposed by the ARDSnet is the most widely used in adult intensive care units in Latin America for calculating ideal body weight.

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### Author's contributions

HAPS and JLEZ. Study planning, data collection, interpretation of the results, data analysis and initial and final drafting of the manuscript.

ECWL. Conception of the original project, study planning, interpretation of the re-

sults, and drafting and approval of the final manuscript.

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### Conflict of interest

None declared.

### Presentations

None declared.

### Appreciations

None declared.

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